Seasonal variation of zooplankton and environmental conditions along a transect in the Gulf of Cádiz

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Abstract: This study presents seasonal variation in the zooplankton composition of the Gulf of Cádiz was studied between 2001 and 2012. Samples were collected three times per year, in the spring, summer and autumn at three stations situated along a transect perpendicular to the coast. The total zooplankton abundance during the summer was higher than in the spring and autumn. Zooplankton community is characterized by a seasonal cycle mirroring similar cycles in the physical environment. Differences in community composition were also found along the transect, particularly between the coastal station, under the influence of the Guadalquivir River, and the outer station, characterized by oceanic conditions. This study is the first description of the seasonal and spatial variation of this marine component of the Gulf of Cádiz.

Key words: *mesozooplankton community, cyclical pattern, time series, SW Spain, European temperate system*

1. INTRODUCTION

Among the plankton components in the South-Iberian Atlantic Margin, the ichthyoplankton is undoubtedly the most investigated group (Baldó *et al.* 2006; Catalán *et al.* 2006; Faria *et al.* 2006; Garcia-Isarch *et al.* 2006; Drake *et al.* 2007). Previous studies on the zooplankton community were restricted to salt ponds of the marshes in the Cadiz Bay and surrounding areas (Yúfera *et al.* 1984; González-Gordillo *et al.* 2003) and in the Cadiz Bay (Benavides *et al.* 2010) and specific taxonomic study on decapod larvae from the coastal region of south-western Europe (Dos Santos and Gonzalez-Gordillo, 2004). Studies in the oceanic region are usually limited to one single period, not enough to resolve seasonal variability (Rubin *et al.* 1997; Villa *et al.* 1997; Mafalda *et al.* 2007; Macias *et al.* 2010). Several reports have highlighted the lack of knowledge about zooplankton temporal and spatial variability in the Gulf of Cádiz (GoC) (ICES, 2011; 2013). Additionally, little is known about the response of zooplankton to environmental factors. As in most organisms, large-scale abiotic drivers, such as climate swings, affect the density and composition of zooplankton due to their short life-cycle and rapid numerical responses to environmental changes (Beaugrand *et al.* 2009). Long-term biological datasets provides unique ecosystem information to assess spatio-temporal community dynamics in response to environmental forcing (Beaugrand *et al.* 2009; Llope *et al.* 2012). Zooplankton are good indicators of climate change and play a critical role in marine food webs, transferring energy from primary production to high trophic levels (Hays et al. 2005). Owing to these factors, a basic understanding of the zooplankton community changes and the relations between the multiple ecosystem components is needed. The present study aims, for the first time, at understanding the key structuring mechanisms in zooplankton community of the GoC. Specifically, we aimed to: i) describe the seasonal variation in the community and; ii) identify relations between environmental variables and zooplankton.

2. MATERIAL AND METHODS

2.1 Study area

This study was conducted in the upper half of the GoC (SW Iberian Peninsula) (Fig. 1). The GoC hydrography is characterized by a strong seasonal cycle, typical of temperate seas. Three processes are known to disrupt this general pattern: (i) upwelling events; (ii) the Mediterranean waters and; (iii) discharge of the Guadalquivir River (ICES, 2013). The Guadalquivir Estuary has a strong influence on the biological productivity, being a source of nutrients and organic matter to the basin and a recognized nursery area for post-larvae of several species, including some commercially important (e.g. *Engraulis encrasicolus*, *Sardina pilchardus*) (Drake *et al.* 2007; González-Ortegón *et al.* 2015). Consequently, the specific oceanographic conditions in this coupled-system may influence the productivity and communities present there.

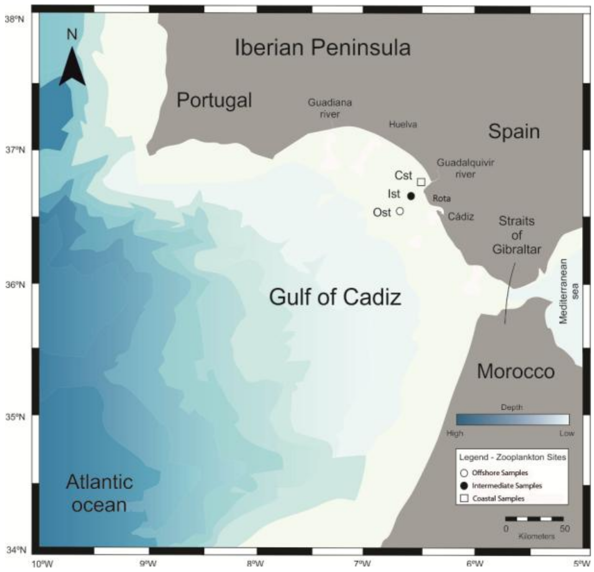

Fig. 1. Map showing the sampling sites in the Gulf of Cádiz. Legend: Coastal site – Cst; Intermediate site – Ist; Offshore site - Ost.

2.2 Sample procedure

Zooplankton samples were gathered from surveys conducted during several research projects where the IEO was involved named “GOLFO”, “FLUTUACCIONES” (Fluctuations and Potential of fisheries species in the Andalusian Atlantic region) and “STOCA” (Oceanographic time series data in the Gulf of Cádiz) between 2001 and 2012. Three locations along a transect off the mouth of the Guadalquivir were selected in the present study. Samples were taken using a Bongo net of 40-cm mouth diameter and 200-µm mesh size, equipped with flowmeters "General Oceanics 2030R". Environmental data compiled in this study correspond to an 8-day composition previous to the sampling day at the corresponding station sites. Sea surface temperature (SST) and chlorophyll *a* (Chl a) dataset were acquired from the measurements by Ocean color satellite sensors (Aqua-MODIS, level-3 - spatial resolution - 4km; /oceancolor.gsfc.nasa.gov/). Freshwater discharges from the Alcalá del Río dam were provided by the Regional River Authority (Confederación Hidrográfica del Guadalquivir). Winds and rain dataset were obtained from the meteorological station of “Rota” and provided by the State Meteorological Agency (Agencia Estatal de Metereologia).

2.3 Data analysis

One and two-way ANOVA was tested to assess differences in abundance data between seasons and sites, respectively. Significant differences in zooplankton community between seasons, and sites were performed using the One-way ANOSIM permutation test. The contributions from each variables driving to the dissimilarity between those groups were identified by the SIMPER analysis. Both analyses were realized on the log-transformed abundances data, in order to reduce the influence of the most common and rare *taxa*, and based on the Bray–Curtis similarity, using PRIMER version 5.0 (Clarke & Warwick, 1994). Exploratory analysis based on Spearman Correlation Coefficient (SCC) between zooplankton abundance versus environmental variables was used to understand which factor influences the zooplankton community. The ANOVA, SCC and graphs were generated using R software (R Development Core Team, 2015).

3. RESULTS

3.1 Physical scenario

During the sampling period, the sea surface temperature (SST) ranged from 14.24 to 27.11 °C (Fig.2). Chl *a* ranged from 0.17 to 36.82 mg $m^{3,}$ showing maximum values during the spring. Peaks of water discharges (0,66-216,2 hm^3/day) and of wind speed (7,9-29,8 km/h) were recorded in spring, indicating a strong signal of freshwater input and mixing sea surface for the Gulf of Cádiz (Fig. 2).

3.2 Zooplankton community

A total of 80 mesozooplankton taxa were identified. Other 72 taxa were larval forms (n =14), not identified (n =13) or grouped into related taxa (eg. Families, genera) (n =45). Among registered groups, copepods were the highest in diversity and abundance across stations, followed by cladocerans, crustaceans and chaetognats (Fig. 2). The most frequent species were *Penilia avirostris, Paracalanus parvus, Oithona sp., Pleopis polyphaemoides, Centropages ponticus* or larval stages (copepodits and unidentified), corresponding to >70% of the samples in all stations. The highest abundance values from zooplankton groups, as well the species diversity, were recorded during the summer (480–27063 individuals m^3) while the lowest abundance were noted in the spring and autumn (245-3978 and 189–4864 individuals m^3, respectively). The SIMPER analysis shows that the copepods contributed mainly to the similarities between seasons and sites (>70%) and also revealed average dissimilarities in mesozooplankton composition between the groups from 28.6% (Ist and Ost) to 32.6% (Spring–Summer). Significant differences in zooplankton composition were found between seasons (ANOSIM; R = 0.40; p < 0.01) while differences between sites were not detected in (ANOSIM; R = 0.57; p < 0.01). The expansion of space-time series may explain these fluctuations and changes in the zooplankton community.

3.3 Zooplankton vs. Environmental variables

The exploratory analyses from the environmental variables of interest in this study were significantly correlated, as assessed by Pearson's correlation coefficient (Fig.3). As expected, there was a positive correlation between SST with cladocerans and Chaetognaths ($r = 0.27$ and $r = 0.22$; $p < 0.01$). Additionally, Cladocera, Copepoda and Larvacea were positively correlated with the speed of winds (r = 0,11; r = 0.27; r = 0.31, respectively). Initial results indicate that all groups were negatively correlated with water discharges (between the lowest, Crustacea, r =-0,07; and highest, Crustacea = -0,14).

4. DISCUSSION

The zooplankton community undergoes clear seasonal changes following those of the physical environment. The values of mesozooplankton abundance observed in the present study are similar compared with other studies of the Iberian Peninsula (Rubin *et al.* 1997; Villa *et al.* 1997; Mafalda *et al.* 2007). The preliminary integrated analysis of different datasets presented here shows a productive and diverse zooplankton community. Similarity among sampling points in our studied transect were explained under the strong estuarine influence of the Guadalquivir river, however significant spatial differences would be expected as we move away from estuarine influence area. When evaluating about the last 20 years, based on data obtained by Villa et al. (1997) and Mafalda et al. (2007) between 1993-1995 and this work (to 2012), we can see that the mesozooplanktonic communities in the SW Iberian Peninsula is diverse and dominated by copepods and cladocerans species, with well-defined seasonal cycles, and directly influenced by specific physical conditions such as Atlantic waters, discharges of rivers, upwelling events, biological productivity and global changes. The relationship of these variables with zooplankton communities and other associated vectors help clarify the trends of key populations for marine resources.

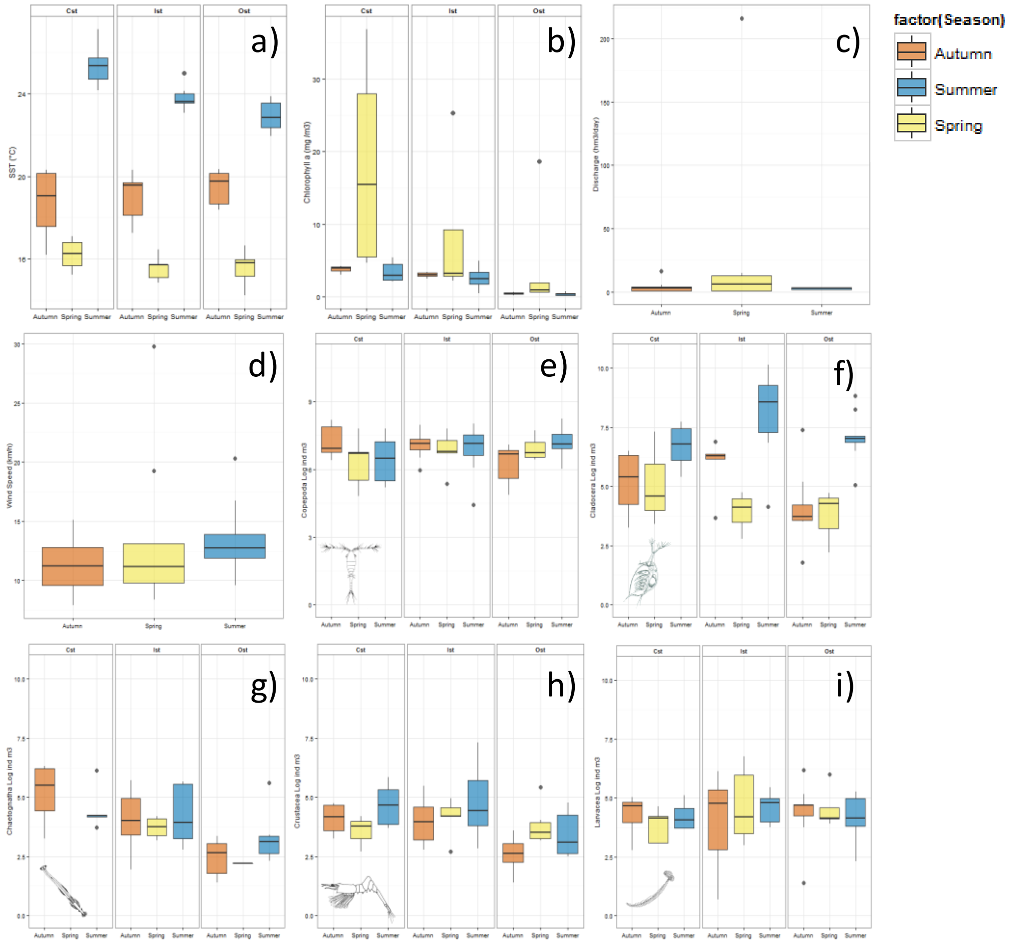

Fig. 2. Seasonal variation of zooplankton and environmental variables in the GoC. Legend: Coastal site - Cst; Intermediate site - Ist; Offshore site - Ost; Sea Surface Temperature - A; Chlorophyll - B; Water Discharge - C; Wind Speed – D; Copepoda - E; Cladocera – F; Chaetognatha – G; Crustacea – H; Larvacea – I. Autumn - Orange; Spring - Yellow; Summer – Blue.

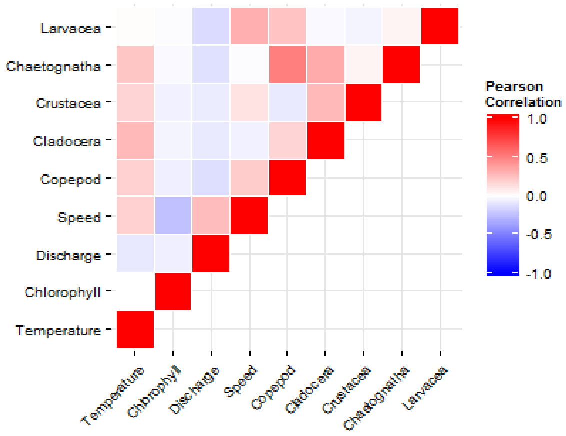

Fig. 3. Correlations between zooplankton community and environmental variables in the GoC.

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